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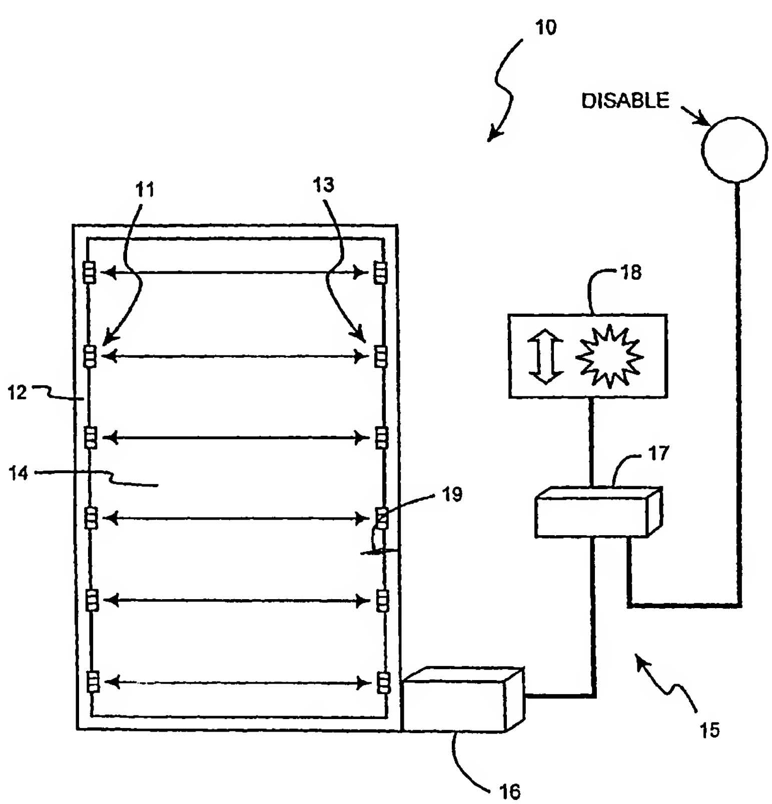

(57) Abstract: An MRI protector for protecting personnel and the MRI apparatus from the introduction of ferrous articles into the magnetic field of the MRI has an array of Hall effect sensors oriented to scan the magnetic field of the MRI. The Hall effect sensors are oriented to scan the magnetic field at the access door of the shielded MRI room. The sensors are connected to a central processing unit (CPU) which analyses the output of the sensors and propagates a warning when the presence of ferrous articles affects the magnetic field of the MRI.

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MRI PROTECTOR

This application is a continuation-in-part of United States Application Serial Number 10/095,543, filed March 11, 2002.

FIELD OF THE INVENTION

This invention relates to the field of medical diagnostics and, specifically, to protection of personnel and equipment involved in MRI diagnosis.

BACKGROUND OF THE INVENTION

The use of magnetic resonance imaging (MRI) as a diagnostic tool is a fairly recent innovation in the medical field. This new apparatus allows a detailed view of the bone and tissue inside the body of a patient. The diagnostic device has become an invaluable tool for imaging and exploring the internal body without surgery. MRI has the ability to distinguish healthy and diseased tissue, fat and muscle, and between adjacent structures within the body which other modalities cannot demonstrate. MRI utilizes safe radio waves and a magnetic field to generate the images processed by a computer.

In operation, a typical MRI apparatus relies upon hydrogen protons which have a dipole movement and therefore behave as would a magnetic compass. In MRI scanning, the MRI apparatus operates as a large magnet wherein the protons align with the strong magnetic field but are easily disturbed by a brief radio frequency pulse of very low energy so as to alter their alignment. As the protons return to their orientation with the magnetic field, they release energy of a radio frequency that is strongly influenced by the biochemical environment. The released energy as detected and mathematically analyzed for display as a two dimensional proton density image according to the signal intensity of each tissue.

As with any new equipment, there is a learning curve for the personnel using the device. Partly because of the expense of the apparatus, most MRI machines are in hospitals or other large facilities which have other employees in addition to

those especially trained to use the machines. These other employees also must have some training in the operation of the devices and, especially, any potential dangers associated with the use of the apparatus.

The potential dangers associated with MRI machines include the presence, within the apparatus and surrounding area, of a strong magnetic field. Also, there is the presence of a vacuum vessel, within the apparatus, housing super cooled liquefied gas. On the one hand, the magnetic force may convert loose metal objects into unguided missiles directed at the MRI apparatus and, on the other hand, puncture of the vacuum vessel would be catastrophic. There have been reports of injuries and at least one fatality involving iron, steel and other metal objects striking personnel within the vicinity of an MRI apparatus. These objects have been unwittingly introduced into the magnetic field of the MRI.

Usually, the MRI device is located within a shielded room for improved results and also to lessen the impact of the device on surrounding operations. However, the problem persists of metal objects being negligently introduced into the magnetic field by personnel entering the room or the extended magnetic field of the MRI apparatus.

DESCRIPTION OF THE PRIOR ART

Metal detectors usually used to detect magnetizable metal objects, both ferrous and other metals, such as hand held wands, use battery powered active pulsing electric coils and measure the change in the inductance in the coil. These devices are commonly used to search people for metal objects and to search for buried metal objects, such as mines or treasure. The operation of the coils can interfere with the imaging of the MRI apparatus.

The Hall effect sensors are one type of passive detectors which monitor an established magnetic field and detect changes in the magnetic field produced by introduction of a ferrous object into the field.

U. S. Patent No. 5,444,966 issued August 29,1995 to Strosser et al discloses a ferrous metal detector for use in a harvester to protect the internal mechanism from ferrous objects ingested by the machine. The metal detector includes both Hall effect sensors and permanent magnets. The magnets are necessary to establish

the magnetic field monitored by the sensors. The magnets and the sensors are specifically oriented in regard to each other for maximum coverage and sensitivity.

U. S. Patent No. 4,990,850 issued February 5, 1991 to Votruba discloses a device to scan patients before nuclear magnetic resonance (NMR) procedures to determine if ferrous objects are present in or on the patient. The device includes both magnets and Hall effect sensors to monitor the magnetic field. The signal of the sensors varies as the magnetic field changes with the introduction of a ferrous object into the field.

What is needed in the art is a simple array of sensors, without associated magnets, to generate an alarm when ferrous objects enter the magnetic field of an MRI apparatus.

SUMMARY OF THE INVENTION

Disclosed is an apparatus for protecting personnel and the MRI apparatus from the introduction of ferrous articles into the magnetic field 6f the MRI unit. The apparatus employs an array of passive magnetic field sensors oriented to utilize the fringe magnetic field of the MRI. The sensors do not produce a magnetic field and the sensors do not interfere with the magnetic field of the MRI unit. Examples of such sensors include Hall effect sensors, anisotropic magnetoresistive sensors, and giant magnetoresistive sensors. The sensors are connected to a central processing unit (CPU) which analyses the output of the sensors and propagates a warning when the presence of ferrous articles affects the magnetic field of the MRI.

Accordingly, it is an objective of the instant invention to prevent the introduction of ferrous objects into the magnetic field of an MRI apparatus where their uncontrolled movement may become a danger to personnel and the MRI apparatus.

It is a further objective of the instant invention to teach the use of the magnetic field of the MRI apparatus, itself, to detect ferrous objects by an array of the passive sensors (e.g., Hall effect or anisotropic magnetoresistive) connected to a central processing unit, including a pre-amp and signal processor, to generate an

alarm when a ferrous object impinges on the magnetic field of an MRI apparatus. In this way the MRI apparatus inherently protects itself.

It is a another objective of the instant invention to teach the deployment of the array of the passive sensors to scan the residual magnetic field that exists in the vicinity of an MRI apparatus and recognize the characteristic signature of ferrous intrusions.

It is yet another objective of the instant invention to teach the placement of the array of the passive sensors at the access door to the room housing the MRI apparatus.

Other objectives and advantages of this invention will become apparent from the following description taken in conjunction with the accompanying drawings wherein are set forth, by way of illustration and example, certain embodiments of this invention. The drawings constitute a part of this specification and include exemplary embodiments of the present invention and illustrate various objects and features thereof.

BRIEF DESCRIPTION OF THE FIGURES

Fig. 1 is a diagrammatic representation of the detector of this invention.

DETAILED DESCRIPTION OF THE INVENTION

The ferrous detector 10 includes an array of passive magnetic field sensors located near the access doorway 12 of the shield room housing the MRI apparatus (not shown). In one example the passive sensors are Hall effect sensors, and in another the passive sensors are anisotropic magnetoresistive sensors (AMR). Still further it is to be appreciated that the passive sensors are any passive magnetic sensors that are capable of sensing the magnetic field without affecting the magnetic field, such other examples include giant magnetoresistive sensors (GMR). The array may be mounted on the doorway 12 or they may be carried by vertical arms of a mobile cart (not shown). The array has a series of sensors 11 and 13 on each side of the doorway orientated to horizontally scan the vertical plane of the opening.

Each of the sensors in the series of sensors 11 and 13 are connected to an electronic central processing unit (CPU), generally designated 15, which receives the output of the sensors.

The residual lines of magnetic force of the magnet in the MRI apparatus pass through the access opening 14 generally normal to the scan of the sensors (e.g., Hall effect, AMR, GMR). The passive sensors in the series 11 and 13 are sensitive to the magnetic force lines along one axis and produce a signal related to magnetic field strength. As a ferrous object (not shown) approaches the access doorway 12, the residual magnetic field is disrupted. The output of some or all of the passive sensors of the series of sensors 11 and 13 changes in response to the change in the magnetic field depending on the size, spatial location, and speed of the ferrous object.

The-CPU 15 includes a pre-amp/pre-processor 16 connected to the sensors of the series of Hall effect sensors 11 and 13.

The pre-amp/pre-processor 16 eliminates interference and establishes a usable signal which is amplified into a stabilized signals from the sensors to the signal processor and alarm generator 17. The signals processor/alarm generator 17 analyses the incoming signals from the pre-amp and determines, based on programmed parameters, whether or not to generate an alarm. For example, the analysis may include: a band pass filter to allow signals to be analyzed over time to determine speed of approach with upper and lower limits set to prevent generation of an alarm, or if all sensors are affected equally, no alarm is generated. The signals may be analyzed over time to determine speed of approach with upper and lower limits to prevent generation of an alarm.

The alarm may be aural or visual or both. The alarm may include activation of other mechanical devices to protect the immediate area of the MRI apparatus.

The alarm may be located within the MRI room or in the approach hall thereto. Of course, the signal processor may be operatively connected to the door of the MRI room, as a kicker to close the door or to the door lock (not shown), or other safety devices. The CPU has a display and alarm panel 18 which may be located with the CPU or at a remote location, or both, that may be visible to personnel inside or outside the MRI room.

The detector 10 includes a door position sensor 19 connected to the CPU and the doorway 12. The sensor 19 disables the detector 10 when the door is closed. Of course, the sensor 19 could be attached to the door (not shown).

An additional function of the CPU is a disable command to the Hall effect sensors based on the output trigger signal of the MRI scanner.

It is to be understood that while a certain form of the invention is illustrated, it is not to be limited to the specific form or arrangement of parts herein described and shown. It will be apparent to those skilled in the art that various changes may be made without departing from the scope of the invention and the invention is not to be considered limited to what is shown and described in the specification and drawings.

CLAIMS

1. A protection arrangement for association with an operable MRI apparatus located within a room that has an access opening, the MRI apparatus providing a residual magnetic field that extends to a location of the opening, the arrangement including:

a detector for passively monitoring the residual magnetic field at the location of the opening, the field changing in response to a presence of ferrous material at the opening, the detector including means for outputting a signal indicative of the ferrous material responsive change in the magnetic field; and

means for receiving the change indicative signal and for providing a safety response that addresses the condition of ferrous material at the opening of the room within which the MRI apparatus is located.

2. An arrangement as set forth in claim one, wherein the detector includes at least one passive magnetic field sensor.

3. An arrangement as set forth in claim 2, wherein the means for outputting a signal of the detector includes a portion of the passive magnetic field sensor that has an electrical characteristic that varies in response to changes in perceived magnetic field.

4. An arrangement as set forth in claim 2, wherein the passive magnetic field sensor is a Hall effect sensor.

5. An arrangement as set forth in claim 2, wherein the passive magnetic field sensor is an anisotropic magnetoresistive sensor.

6. An arrangement as set forth in claim 2, wherein the passive magnetic field sensor is a giant magnetoresistive sensor.

7. An arrangement as set forth in claim 2, wherein the detector includes an array of passive magnetic field sensors arranged about the periphery of the opening.

8. An arrangement as set forth in claim 7, wherein the array of passive magnetic field sensors is arranged to have sensor pairs, with each pair having one sensor located at one side of the opening and another sensor located at another side of the opening.

9. An arrangement as set forth in claim 1, wherein the means for receiving the change indicative signal and for providing a safety response includes means for providing a warning alarm.

10. An arrangement as set forth in claim 9, wherein the means for providing a warning alarm includes means for providing an audible alarm.

11. An arrangement as set forth in claim 9, wherein the means for providing a warning alarm includes means for providing a visual alarm.

12. An arrangement as set forth in claim 11, wherein the means for providing a visual alarm includes a visual warning device located inside the room.

13. An arrangement as set forth in claim 11, wherein the means for providing a visual alarm includes a visual warning device located outside of the room.

14. An arrangement as set forth in claim 9, wherein the means for receiving the change indicative signal and for providing a safety response includes means for disabling operation of the MRI apparatus.

15. An arrangement as set forth in claim 1, wherein the means for receiving the change indicative signal and for providing a safety response includes means for disabling operation of the MRI apparatus.

16. An arrangement as set forth in claim 1, wherein the means for receiving the change indicative signal and for providing a safety response includes means for analyzing the change indicative signal and means for determining whether to provide the safety response based upon the analysis.

17. An arrangement as set forth in claim 1, wherein the access opening is a doorway through a wall that bounds the room, the detector being mounted at the doorway through the wall.

18. An arrangement as set forth in claim 1, wherein the access opening is a doorway through a wall that bounds the room, the detector being located in a vicinity of the doorway through the wall.

19. An arrangement as set forth in claim 1, wherein the access opening is a doorway through a wall that bounds the room, the arrangement includes a means to sense a closure position of a door associated with the doorway and means to deactivate the detector in response to a sensed door closed condition.

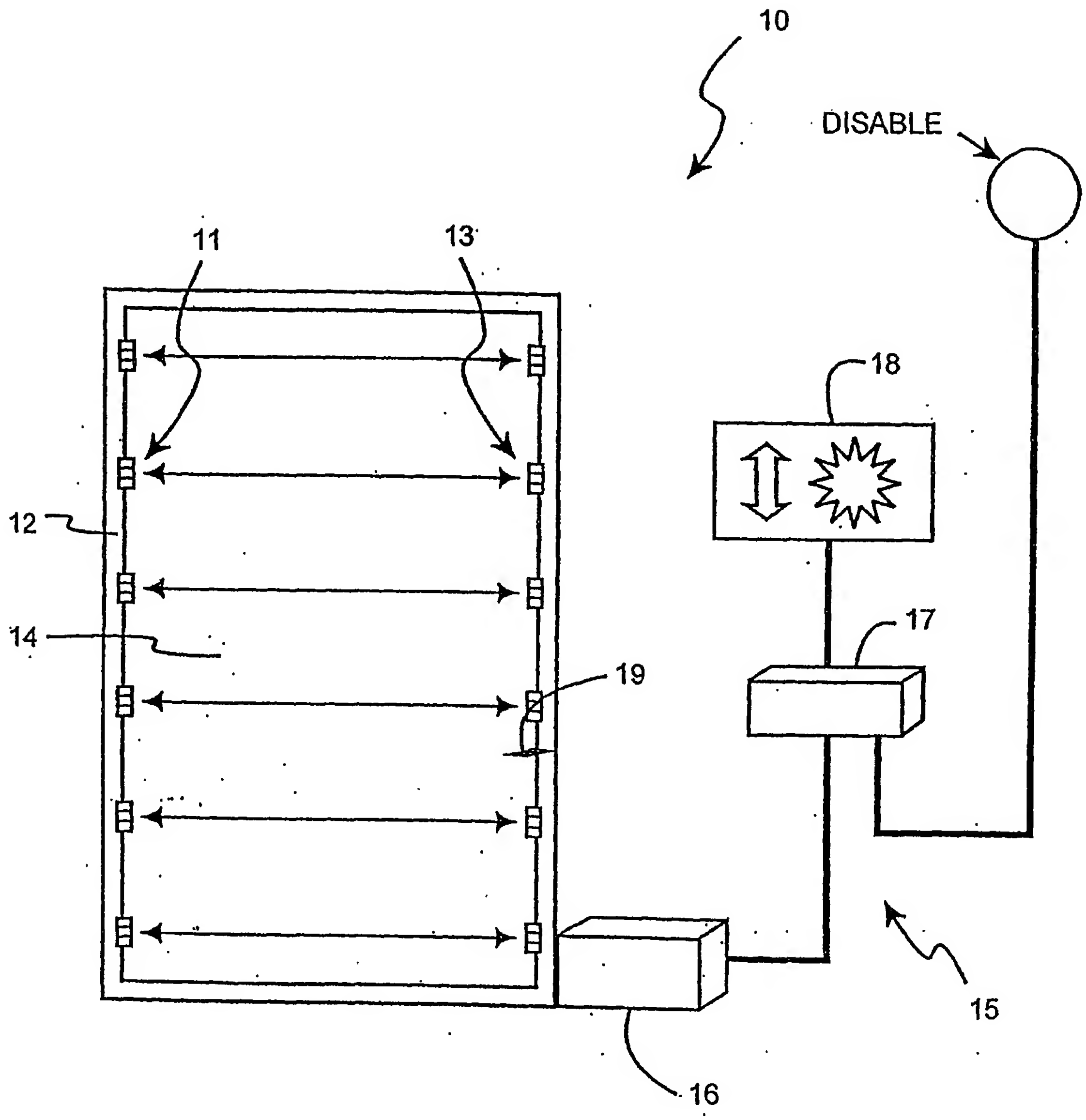

FIG. 1